GridWatch

AI-Powered Early Warning System for European Electricity Grid Stress

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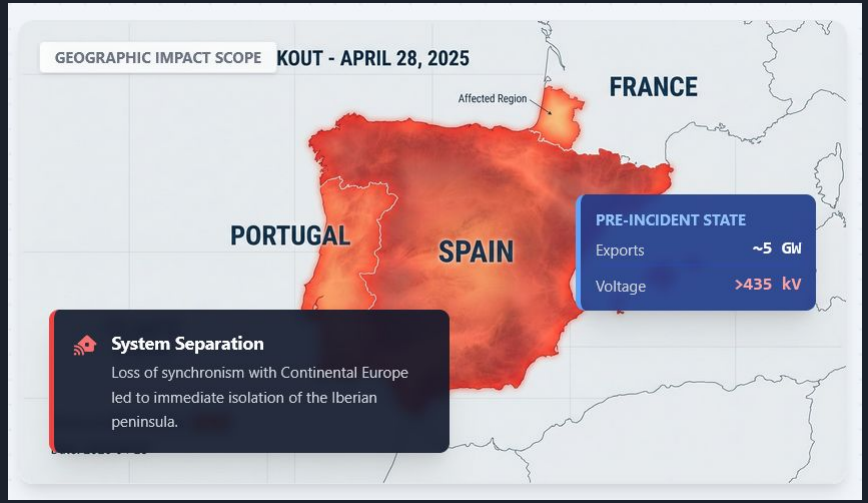
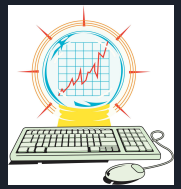
GridWatch Team

Overview

- **28 April 2025:** Massive blackout across Spain and Portugal, impacting tens of millions
- Showed that adequate generation doesn't prevent voltage or synchronization instability
- Proved that capacity margins alone are insufficient
- Generation, demand, and import patterns can still provide early warning signals

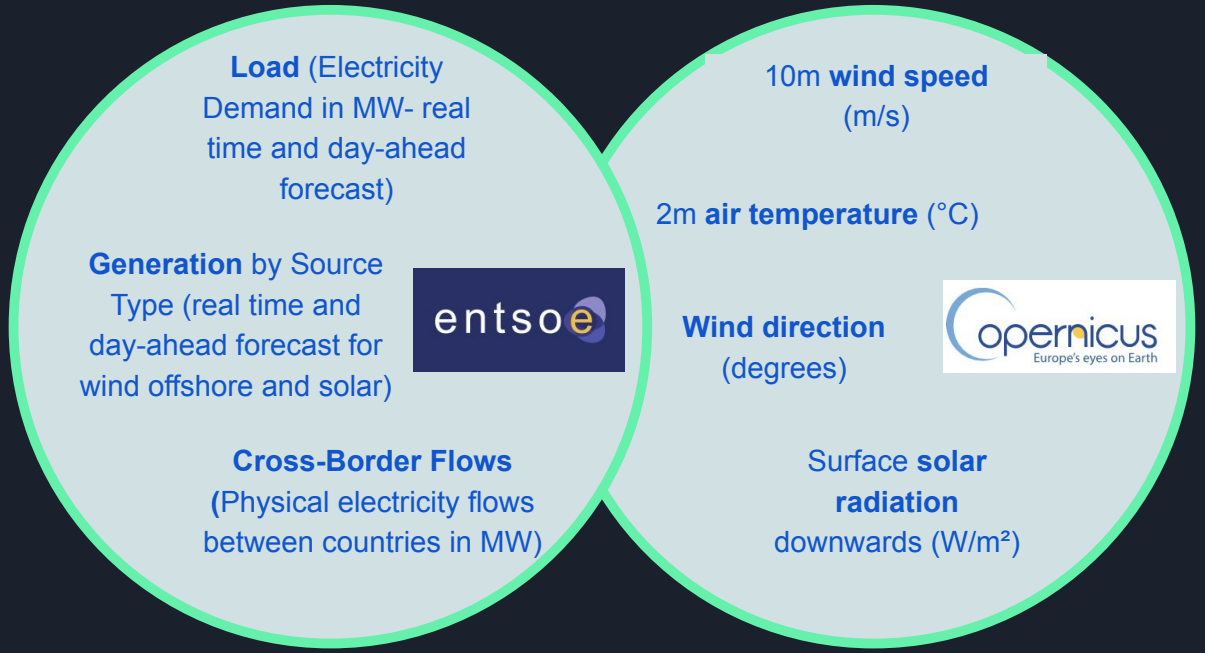


Source: ENTSO-E Factual Report (Published Oct 3, 2025)



Our Goal: build a predictive model for "grid stress / blackout risk" using publicly available time-series data + machine learning.

Data Overview



The **European Network of Transmission System Operators for Electricity** maintains the most comprehensive database of European grid operations.

- January 2023 to October 2025 (2.8 years)
- Total: ~590,000 country-hour observations

Data Preprocessing

databricks

Target variable:
Grid Stress Score (0–100 points)

Quantify real-time system stress using four operational indicators:

1. Reserve Margin

$$\frac{\overline{L}_{24h} - L}{\overline{L}_{24h}}$$

- ≥20% → 0 points
- 10–20% → 12.5 points
- <10% → 25 points

2. Load Forecast Error

$$\frac{L_{\text{forecast}} - L_{\text{actual}}}{L_{\text{actual}}}$$

- ≤3% → 0 points
- 3–10% → 12.5 points
- >10% → 25 points

3. Cross-Border Exports

$\text{Exports} < 10^{\text{th}}\ \text{percentile}$

- Flag = 1 → 25 points
- Flag = 0 → 0 points

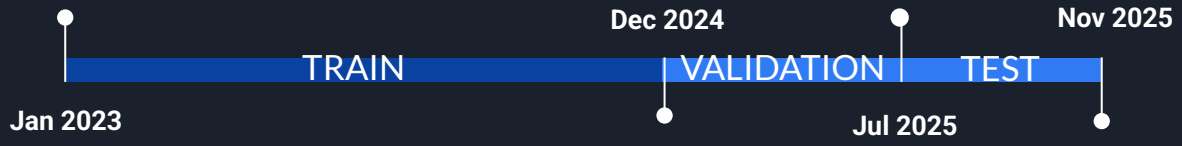
4. Cross-Border Imports

$\text{Imports} > 90^{\text{th}}\ \text{percentile}$

- Flag = 1 → 25 points
- Flag = 0 → 0 points

Data Preprocessing

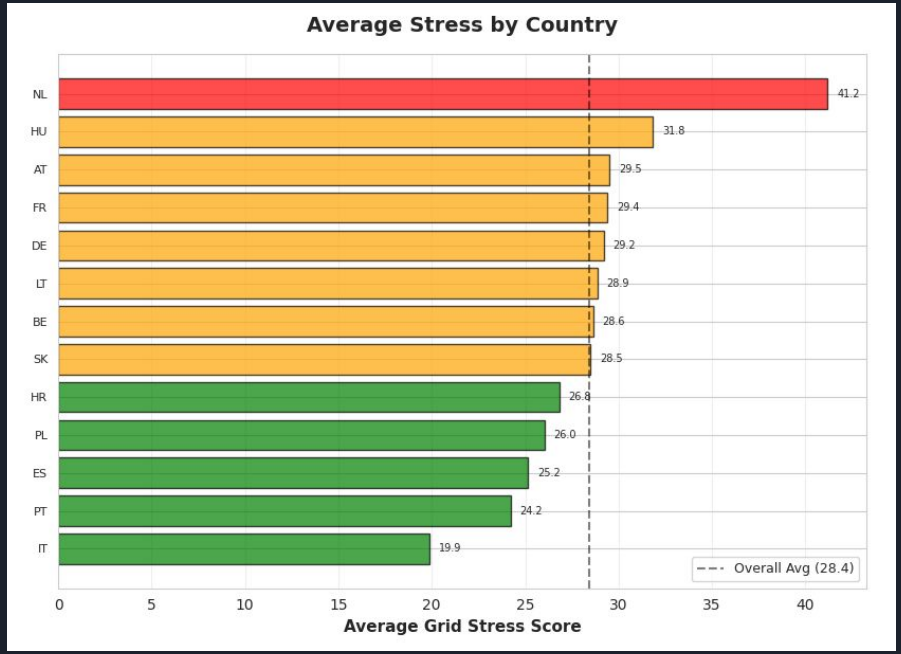
Time-based train/validation/test split



13 countries:

AT DE HR BE PL HU LT NL FR ES IT PT SK

Some insights about grid stress



- NL: high exports and large load forecast errors

Feature Engineering

Grid Features
(Operational Signals)

- Electricity load
- Imports / exports
- Renewable energy output
- Reserve margin

Weather Feature
(External Conditions)

- Temperature
- Wind speed
- Weather variations

Time-Based Features
(Patterns Over Time)

- Lags (1h, 24h)
- Rolling trends (24h-mean, fluctuation level)
- Hour / day / week patterns
- Seasonal trends

Modeling

1. **Time-series model** - ARIMA
2. **Machine learning models:**

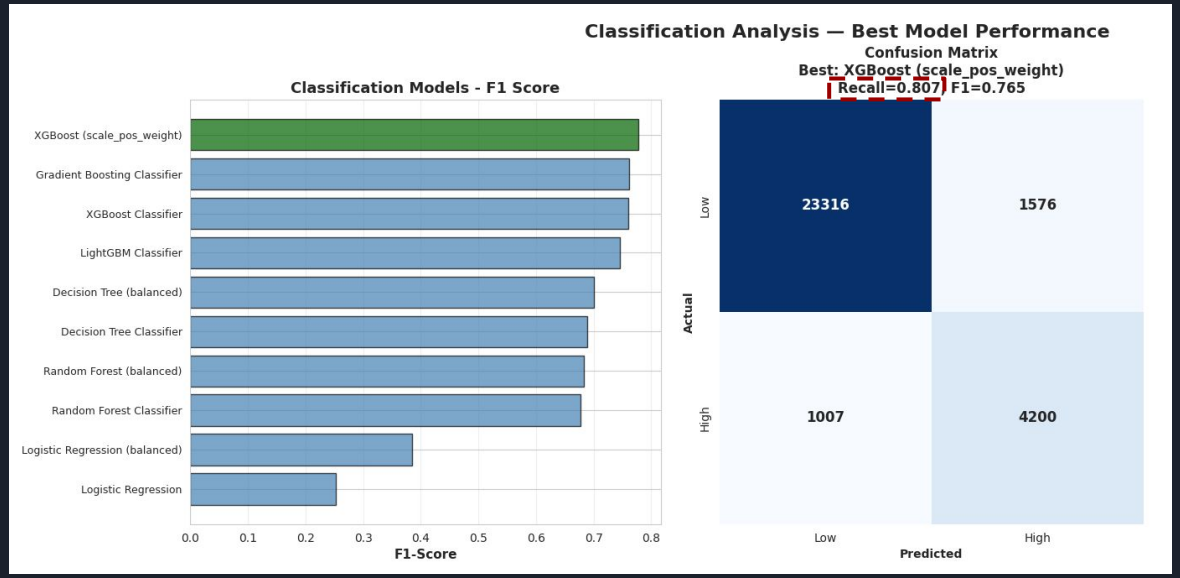
Regression Models

- Linear Models: Linear / Ridge / Lasso
- Decision Tree (default / shallow)
- Random Forests (default / deep / wide)
- Gradient Boosting (sklearn)
- XGBoost (default / deep / regularized)
- LightGBM (default / boosted)

Classification Models

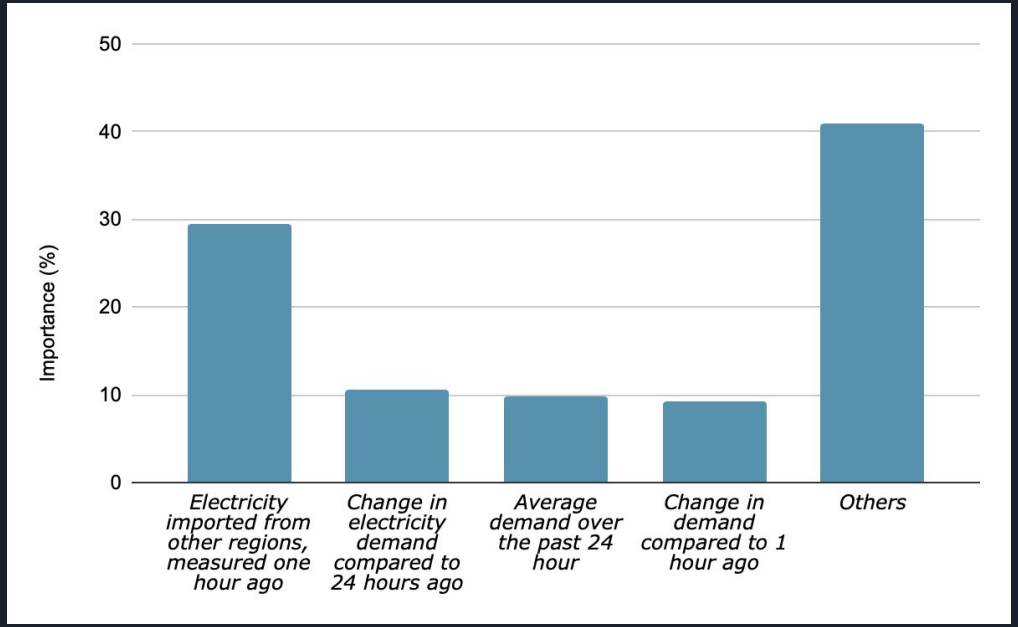
- Logistic Regression (default / balanced)
- Decision Tree Classifier (default / balanced)
- Random Forests Classifier (default / balanced)
- Gradient Boosting Classifier
- XGBoost Classifier (default / scale_pos_weight)
- LightGBM Classifier

Classification Models



- 80% of the high grid stress situations are well predicted

Which factors have the biggest impact on grid stress prediction?



Deploy

Mode

Select Mode

- Simulated
- Live

Country

France (FR)

Scenario Presets

NORMAL OPERATIONS | HEAT WAVE | COLD SNAP | WIND DROUGHT | IMPORT CRISIS | FORECAST ERROR | PEAK HOUR STRESS

SIMULATE BLACKOUT | RESET

Scenarios Note:
Preset scenarios modify grid conditions, but the final stress score always comes from the model's learned patterns.

Load Parameters

Actual Load (MW)
48737
24368 97474

Forecasted Load (MW)
48737
24368 97474

FORECAST ERROR: +0.0%

Cross-Border Flow

GridWatch

STRESS PREDICTOR

FR France Grid Status

Stress prediction • 2025-12-10 19:05 UTC

STRESS SCORE	CURRENT LOAD	NET IMPORTS	TARGETS TRIGGERED
15.4	48,737 MW	7,486 MW	1/4
▼ 14.0 vs Baseline	▼ 0.0% vs forecast	Exporting	+25 pts

Stress Gauge

15.4 pts

Underlying cause (component contribution)

Target Analysis

Reserve Margin	Load Forecast Error	T7: High Exports	T8: High Imports
✓ Normal	✓ Normal	+25 pts	✓ Normal

6-Hour Projection

Feature Importance

TOP 10 FEATURE IMPORTANCE

Thank you!

App:
https://gridwatch-energy-grid-stress-prediction.streamlit.app/

GitHub Repository:
https://github.com/chavelyalbert/energy-grid-load-prediction